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Some Speculations on a Causal Unification of Relativity, Gravitation, and Quantum Mechanics

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Abstract

Some speculations on a causal model that could provide a common conceptual foundation for relativity, gravitation, and quantum mechanics are presented. The present approach is a unification of three theories, the first being the repulsive theory of gravitational forces first proposed by Lesage in the eighteenth century. Lesage attempted to explain gravitational forces from the principle of conservation of momentum of some hypothetical particles, which we shall call gravitons. These gravitons, whose density is assumed homogenous, are constantly colliding with objects. The gravitational force is caused by a shielding effect of bodies when they are near each other. One also can make a clear physical distinction between an accelerating and a nonaccelerating object from this viewpoint. The second of these theories is the Brownian motion theory of quantum mechanics or stochastic mechanics, which treats the nondeterministic nature of quantum mechanics as being due to a Brownian motion of all objects. This Brownian motion being caused by the statistical variation in the graviton flux. The above two theories are unified in this article with the causal theory of special relativity. Within the present context, the time dilations (and other effects) of relativity are explained by assuming that the rate of a clock is a function of the total number or intensity of gravitons and the average frequency or energy of the gravitons that the clock receives. Two clocks having some relative velocity in the same intensity gravitational field would then have a different rate because the average frequency of the gravitons would be different for each clock owing to the Doppler effect. That is, they would essentially be in different fields considering both the frequency and intensity. The special theory would then be the special case of the general theory where the intensity is constant but the average frequency varies. In all the previous it is necessary to assume a particular model of the creation of the universe, namely the Big Bang theory. This assumption gives us the existence of a preferred reference frame, the frame in which the Big Bang explosion was at rest. The above concepts of graviton distribution and real time dilations become meaningful by assuming the Big Bang theory along with this preferred frame. An experimental test is proposed.

1. *Introduction*

"Once a theoretical idea has been acquired one does well to hold fast to it until it leads to an untenable conclusion."

A. Einstein

In this article some speculations are presented in an attempt to find a common conceptual basis for the areas of Relativity, Gravitation and Quantum Mechanics. The word "speculations" is used because this is strictly a qualitative article, and as such no serious pretensions can be made that a bonafide scientific theory is being presented. We do feel strongly though that even qualitative considerations have a place in the scientific literature. It is remarked that even on this qualitative level this viewpoint leads to two direct contradictions with the existing Theory of Relativity. Unfortunately, only one of these effects appears to be testable at this time. This is discussed in Section 8.

Since gravitons play a basic role in this model we call it the Graviton Model or GM for short. For convenience all the axioms needed for GM are listed in Section 2. In Sections 3, 4, 5 and 6 the areas of Gravitation, Quantum Mechanics, Special Relativity, and General Relativity respectively are reviewed from the stand point of GM. Section 7 discusses some problems that arise from this model. Finally, in Section 8 a feasible experimental test of this viewpoint as applied to Relativity is described.

2. *Axioms*

Several axioms are needed in order to develop GM. We prefer to list them all in one section so that the development of each area is not disrupted. The meaning of each axiom should gain clarity from the context in which they are used in the different sections.

(1) The Big Bang Theory of the creation of the universe is correct. That is, at one point in time all the matter and energy in the universe was concentrated in one small portion of space. Then there was a cataclysmic explosion. This explosion forced the matter and energy (photons, gravitons, etc.) to be distributed throughout the universe reaching the form we now see. The hypothetical reference frame in which this explosion was at rest is called SP, for the preferred reference system.

It will be seen that from the point of view of the Special Theory of Relativity this frame plays the role of the classical ether frame.

(2) All photons and gravitons have the velocity c in vacuum relative to SP when they are not "bound" to some particle. A graviton by definition is assumed to be those "special" photons which for reasons not understood are responsible for all gravitational effects. A photon is assumed to be strictly a particle concept. Any type wave considerations are only considered to be some mathematical formalism.

(3) It is also assumed that both the intensity and frequency distribution of gravitons are uniformly distributed in an isotropic manner relative to SP (except possibly for small irregularities near objects) in a large section of the universe which includes our galaxy. Also the graviton density is such that in any small volume of space there are "many" of them.

With the present assumption, SP sees the same number of gravitons of each frequency in all spacial directions per unit time interval of his. A reference frame S having a constant velocity relative to SP would not see the isotropy because of the Doppler Effect which we assume applies to gravitons. S would observe all the gravitons to have their frequency blue shifted in the direction of the velocity and red shifted in the opposite direction. If one uses the relativistic doppler formula the average frequency S would receive is blue shifted.

This assumption of isotropy is not necessary. It is made principally for convenience at this point. The reason it is not necessary is roughly because of the proportionality of inertial and gravitational mass. This will be gone into further at another time.

(4) All matter objects (i.e. anything traveling at a velocity less than the speed of light relative to SP) have the property that when they are hit by a graviton the matter object momentarily "absorbs" the graviton and then emits it at some angle relative to its original direction. This angle is a function of the frequency of the graviton and the velocity of the object relative to SP.

(5) Given a fixed density or flux of gravitons the number absorbed by an object is proportional to a property only of that object which we call its mass.

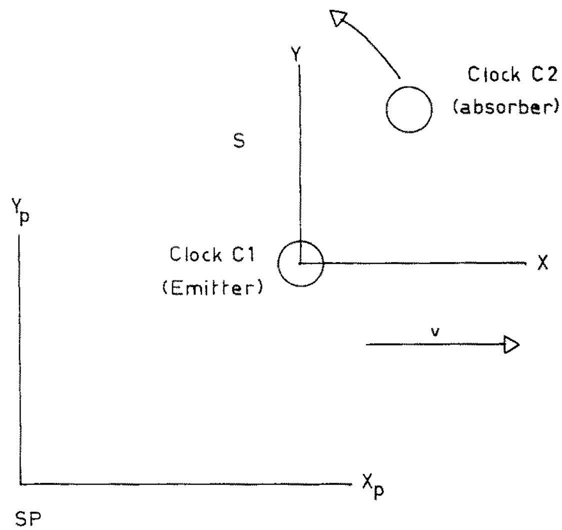

Figure 1—S has a velocity v relative to SP. C2 is a clock (gamma ray absorber) rotating in a circle with a tangential velocity of w relative to S. C1 is an identical clock (gamma ray emitter) fixed at the origin of S. w is assumed to be less than v for convenience. The plane of the diagram should be considered as the plane of the surface of the earth for some of the references to this figure.

Also the number of gravitons absorbed by an object is very "small" compared with the density of the gravitons.

(6) Only objects traveling at the speed of light have momentum and inertia as attributes intrinsic to themselves. Matter objects in themselves have no inertia or momentum. Matter objects acquire these attributes only from the gravitons. That is, a matter object is constantly being hit by many gravitons at any instant; only by virtue of these gravitons and the object's ability to absorb and emit these gravitons does the object acquire its inertia and momentum.

(7) The rate of a clock and the length of a rod are functions of the total number and average frequencies of the gravitons that they receive. The rate of a clock and the length of a rod (in a uniform gravitational field) are given by the expressions

$$\Delta t = \Delta t_0/\sqrt{1 - v^2/c^2} \qquad \text{and} \qquad \Delta l = \Delta l_0\sqrt{1 - v^2/c^2}$$

respectively, where Δt_0 and Δl_0 are the rest values in SP and v is their velocity relative to SP. These contractions are considered real contractions. The word "real"[1] is used in its intuitive sense, the same sense in which one would use it in Lorentz's ether theory (Lorentz, 1923).

3. *Gravitation*

This section discusses the classical theory of gravitation from the point of view of GM. To explain gravitational forces we use a modification of a theory of of Lesage which dates back to the eighteenth century, as given later by Prescott (1877).

A. With the first six assumptions of Section 2 gravitational forces can be explained in terms of the conservation of momentum of the gravitons. If we have a matter object O1 stationary in SP then it would remain stationary (except possibly for very small movements due to some statistical fluctuations in the graviton flux) because the momentum it receives from the gravitons is balanced via Assumption (2.3) (isotropy). Now if we put another matter object O2 in the neighborhood of O1 then the isotropy around O1 would be lost. Object O2 would have absorbed some gravitons and emitted them at some angle. This can destroy the isotropy around O1. Analogously, the presence of O2 can destroy the isotropy around O1. Therefore, O1 and O2 would be forced towards each other. Remember we assume an object absorbs only a small number of the available gravitons so O1 and O2 would still receive gravitons from all directions (i.e. have inertia in all directions) but it would be unbalanced. Just from geometrical considerations it is clear that the "strength" at which they are being forced together, or the force between them, is inversely

[1] The objection that the concept of real time dilation is not well grounded because it may have no objective experimental significance is no more valid than the objection that the concept of inertial frame is invalid because it has no objective experimental significance.

proportional to the distance between them and proportional to the product of the ability of each object to absorb gravitons. Thus Newton's Law of Gravitation can be considered satisfied for matter objects stationary in SP.[2]

B. There is, however, an objection raised by R. P. Feynman (1963) to Lesage's Theory. The objection is as follows: if we give say O1 a velocity, v, then it should naturally slow down because the graviton flux is no longer symmetric about it.

One possible way of overcoming this would be to assume that each graviton is emitted in the direction from which it was absorbed. Then considering both the absorption and emission (action and reaction) momentum there is no imbalance since they would equal each other. This is not satisfactory, of course, since then one could not account for gravitational forces between objects; the density of gravitons would be uneffected by the presence of an object.

But if one considers both the momentum from absorption and emission, and supposes as is done in Assumption (4) that the angle of emission is a function of frequency (the larger the frequency the smaller the angle), then one can obtain a momentum balance. That is, there will be no net forces on an object having a constant velocity, v, even though the symmetry about the object is lost when v is not equal to zero.

Unfortunately there are many ways of obtaining an angle relationship which will satisfy the above. Below we give the simplest way of obtaining a momentum balance in order to illustrate that it can be done.

The particular assumptions made in the following demonstration are by no means necessary to obtain a momentum balance. Let an object OB have a velocity v relative to SP in the plus x-direction. Let N be the total number of gravitons per unit time interval of SP from the plus-x direction that OB would receive if it was at rest in SP. Let P be the average momentum of each graviton. So if OB were at rest in SP it would receive $PR = NP$ momentum per unit time interval from the plus-x direction. Since OB has the velocity v the actual momentum would be $PR = P(1 + v/c)$ per unit time interval of SP. Remember we are doing a momentum balance from SP, so only the number of gravitons will change, and not the average frequency. Likewise the momentum that OB would receive from the minus-x direction would be $PL = P(1 - v/c)$.

Now we must consider the reaction momentum. Let THR and THL be the angles at which each graviton from the plus- and minus-x directions is emitted respectively. It is assumed, since there is no reason to prefer a spacial direction, that the gravitons are emitted uniformly in 360 degrees around the x-axis at these angles THR and THL. This assumption also saves us the trouble of balancing the momentum in any other direction other than the x direction for gravitons originating in the x direction. Also assume that each graviton (relative to SP) does not change its frequency in this absorption–emission process.

So then the emitted gravitons contribute the momenta $PR \cos(THR)$ and

[2] The previous is not satisfying and will be analyzed in detail in a forthcoming article.

PL cos (*THL*) respectively, if we require the momentum to balance we get

$$PR - PR \cos(THR) = PL - PL \cos(THL)$$

which gives

$$(1 + v/c)/(1 - v/c) = (1 - \cos(THL))/(1 - \cos(THR))$$

$$\cos(THR) = \cos(THL)(1 - v/c)/(1 + v/c) + 1 - (1 - v/c)/(1 + v/c).$$

This relationship between *THR* and *THL* gives the desired momentum balance. That is, with this particular angle relationship there is no net force on an object having a velocity $v < c$. This balance is only for the x direction; in reality all directions must be considered. But if we assume each direction balances independently except for a constant multiple, the previous suffices.

C. Notice that in Assumption (2.4) included a time lag between the absorption and the emission of a graviton. This was done to give a distinction between an object having a constant velocity and one having some acceleration.

First note that (always thinking relative to SP in which everything is isotropic) the time difference between emission and absorption is not relevant to the momentum balance for an object with a constant velocity. This is due to the fact that the shifts in frequency and flux in each direction are constant.

But if the object is accelerating, using the assumption that the angle of emission is a function of frequency, which in turn is a function of velocity, one losses the momentum balance. That is, if there is some finite time lag between emission and absorption, any momentum balance that worked for a constant velocity would be lost because the graviton frequencies would be constantly changing.

So GM makes a real physical distinction between an object having a constant velocity and an object not having a constant velocity. That is, it gives a physical basis to Newton's First and Second Laws. Note that this physical distinction is not based on some absolute concept of space. It is based only on the distribution of gravitons, which was initially determined by the Big Bang explosion.

4. *Quantum Mechanics*

A. This section discusses GM in relationship to Quantum Mechanics. The basic viewpoint of a Brownian Motion type interpretation of Quantum Mechanics has been proposed and developed by a number of researchers (see for instance Bohm, Nelson, Dankel, Weizel, Kershaw, Comisar and Fenyes) so this area is reasonably well developed. For instance, Nelson (1966) gives a derivation of Schrodinger's time independent equation. Also see the recent book by Belinfante (1973) which gives a survey of Hidden Variable Theories and a discussion of experimental tests. Only the basic idea is presented here. This area is called Stochastic Mechanics by some researchers (Dankel, 1970).

We imagine that, even relative to SP, the flux of gravitons is not quite perfectly isotropic. There are very small asymmetries due primarily to the presence of matter. So in any given small volume of space we have small statistical variations in the graviton flux. Thus we have here a situation analogous to the Kinetic Theory of Gases. Objects are, so to speak, floating in a sea of gravitons. Because of the statistical variations in the graviton flux, an object would undergo small random motions analogous to Brownian motions. It becomes, at this point, meaningless to speak of identically prepared particles (i.e. same momentum and position). In any set of "identically" prepared particles only an average value of momentum and position would have meaning. Note that GM would differ from the Kinetic Theory of Gases in that the gravitons themselves would very rarely collide. In terms of the Kinetic Theory this would be analogous to a very large mean free path. Also since the universe is expanding, equilibrium conditions between matter and gravitons would not have to eventually come about.

We remark that in the quoted papers the cause of the Brownian Motion is not discussed.[3] It is usually assumed explicitly or implicitly that all particles undergo a Brownian type motion relative to some hypothetical "fluid." Whereas in this discussion, we explicitly postulate the existence of gravitons which cause Brownian Motion. Also, in the terminology of Belinfante (1973) it is not at all clear which type of Hidden Variable Theory the previous Brownian Motion considerations would lead to.

B. On an intuitive level, from the Stochastical Mechanical viewpoint, several important Quantum Mechanical effects become clear. First, there will be a natural statistical indeterminancy in the position and momentum of a particle as there is in Brownian movement. Second, the position of an electron near a nucleus would be smeared rather than fixed because of its proxomity to a large mass. The large mass would introduce larger than normal statistical variations in the graviton flux and only statistical orbits of the electron would have meaning. Third, the quantization of energy would exist because of the very discreetness of the gravitons. Extrapolating from this to try and explain the energy levels of an atom is, of course, another question.

5. *The Special Theory of Relativity*

A. In this section the special theory of relativity is discussed in relation to GM. This is a summary of the viewpoint expressed in Buonomano (1974).

Throughout this section we assume that all reference frames are in a uniform gravitational field. That is, relative to SP the graviton flux is uniform and isotropic. By definition, any reference frame having a constant velocity relative to SP is called an inertial reference frame. See Section 8 for a proposal of an experimental test of this viewpoint.

It is well known that the Lorentz Transformations are easily derivable from the assumptions of a preferred reference frame, real-time dilations and real length contractions (see Buonomano (1974) Section 3, for instance). Since all the other effects of the Special Theory of Relativity are derivable from

[3] An exception to this is apparently Weizel (1953) who postulates the existence of some hypothetical particles which he calls zerons.

the Lorentz transformations plus the Principles of the Conservations of Energy and Momentum, this theory is satisfied by GM from a formal point of view. Since in GM the time dilations (etc.) are treated as being real, we must offer a causal explanation of why clocks have different rates at different velocities. The explanation follows from the Doppler Effect. That is, two clocks having different velocities relative to SP perceive the graviton flux differently because of the Doppler Effect.

For example, if we have a clock initially at rest in SP it receives each graviton frequency in an isotropic manner. If we then give it the velocity v, the clock would then perceive the gravitons blue-shifted in the direction of its velocity and red-shifted in the contrary direction. Using the Relativistic Doppler Formula (see Section 8-B) it is easy to show, after summing over all spacial directions, the clock would see the average graviton frequency blue-shifted.

So from the point of view of GM, the Special Theory of Relativity is a special case of the General Theory in other than an abstract mathematical sense. That is, it is the special case where the intensity of the field is constant, but the frequencies are different for each observer having a different velocity.

The previous mentioned reference (Buonomano, 1974) discusses various aspects of the aforementioned viewpoint including its application to the Twin Paradox.

6. *General Relativity*

In this section the point of view of GM in relationship to the General Theory of Relativity is presented. The Principle of the Equality of Gravitational and Inertial Mass is discussed in Part A, the Principle of Equivalence in Part B, and the three famous tests of the General Theory in Parts C, D and F, respectively. Part E gives an alternate derivation of the time dilation prediction of the General Theory of Relativity.

A. The philosophical spirit of the General Theory of Relativity is maintained in a pleasing manner. First, there is no concept of an absolute space that is presupposed in GM. What defines space is some mean statistical distribution of gravitons. The initial distribution of gravitons being determined by the Big Bang explosion.

Secondly, the concepts of inertial, active and passive gravitational mass all represent one and the same attribute of a matter object, that is, its ability to absorb and emit gravitons. By Assumption (2.5) this ability is only a function of the matter object (given a fixed graviton flux); the graviton density determines the inertial mass of a matter object.[4] The gravitational mass of an object is a measure of a matter object's ability to disrupt the graviton distribution in its neighborhood. But this ability is just its ability to absorb

[4] The situation is actually more complicated in the sense that inertia would also depend on the time lag between the emission and absorbtion of gravitons as discussed in Section 3-C. This will be made clearer at another time.

gravitons, which is the very same attribute which gives it its inertial mass. It is clear that in the previous sentence, it is justified to use gravitational mass as equivalent to both the active and passive gravitational mass.

Mach's Principle may not be satisfied by GM in the following sense. Consider Mach's statement (Mach, 1893) that the earth's rotation would be equivalent to the earth not rotating with all the fixed starts rotating instead. That is, only relative motion is meaningful. In GM, motion is meaningful relative to some mean statistical graviton distribution. If all the fixed starts suddenly began to rotate and the earth stopped rotating, this would certainly effect the graviton distribution, but not necessarily in a manner that would make the above statement of Mach correct.

B. Since the Principle of Equivalence relates strongly to the proportionality of inertial and gravitational mass (see Fock, 1963), it would not be unreasonable to expect its validity in GM. But as far as trying to offer a physical explanation in relation to the graviton flux, we have little of interest to say. It is hoped that the Principle of Equivalence could provide us with some heuristic direction in determining the quantitative structure.

From the point of view of time considerations in GM, there is a fundamental distinction that one is forced to make between a clock in a gravitational field and one undergoing an equivalent acceleration in a zero gravitational potential field. A clock undergoing a constant acceleration would be continually changing its velocity. Therefore, under the assumptions in the section on Special Relativity, the rate of the clock would be continually changing. That is, relative to SP a clock accelerating is always changing its rate, but a clock in some equivalent gravitational field has a constant rate. This we know from experiments. It is noted that the previous considerations do not at all apply to the Principle of Equivalence in regard to its validity in GM since the Principle of Equivalence is a local principle.

C. Qualitatively, the bending of light rays in a gravitational field presents no problem since gravitons would collide with other gravitons as well as photons.

D. In Assumption (2.7) and in the section on Special Relativity it was assumed that the rate of a clock and the length of a rod is a function of the total number and the average frequency of the gravitons they receive. For the case of a clock or a rod in an isotropic field an explicit formula was given. That formula was naturally motivated to give us agreement with the Special Theory of Relativity.

We have no similiar explicit formula for the case of a varying gravitational field; in fact the situation appears to be even worse in the following sense. We know from experience (Pound & Snider, 1963; Hafele & Keating, 1972) that the stronger the gravitational field the slower a clock. First, remember that in GM a stronger gravitational field is actually a "field" of lower graviton density. For example, the graviton density increases as we go away from the earth. Thus, the more gravitons (i.e., the more energy) a clock receives the faster it runs. But it is clear from the section on the Special Theory of Relativity that the faster a clock goes (relative to SP) the greater the average frequency of the gravitons that it would receive, yet the clock runs slower in this case. If one were to use total gravitational energy that a clock received as a criteria for its rate, a contradiction would result. This problem can be overcome for clocks whose essential mechanism is simply a rod with mirrors fixed at both ends and a device for counting the number of reflections of some light. If one is following a deterministic viewpoint of physics this model is probably quite reasonable for a number of types of clocks in the sense that a clock is a sequence of cause- and effect-related events where the cause–effect relationship is transmitted at the speed of light. Now if one assumes that the essential nature of time is simply a reflection of the fact that cause–effect relationships are always transmitted at a finite velocity, then anything effecting the transmission of this cause–effect relationship would effect the rate of a sequence of these events, consequently the rate of a clock. For instance, in the Special Theory we can assume, as we did, that the length of a rod decreased with increasing velocity because of the increase in graviton momentum brought about by this increase in velocity. If there were no other effects to consider then we would be forced to conclude that this type of clock would run faster as its velocity increased. But if we consider the process from the perspective of SP it is easy to see considering both the movement of the apparatus and the shrunken rod that the number of reflections would decrease with increasing velocity. It is also easy to see that this effect does depend on the orientation of the rod. To see the previous one uses the same type reasoning that one would use to explain the negative results of the Michelson-Morley Experiment from an ether interpretation. Now as stated in the previous paragraph the higher a clock is above the surface of the earth the greater the graviton flux it experiences. Therefore a rod would receive more momentum and therefore would be shorter (if it had the appropriate orientation) than a clock nearer to the surface of the earth. Then the above type clock, since we can ignore motions in this case, would run faster as its height increased. Its rate in this case would also be a function of its orientation. Of course the previous assumption that a rod becomes shorter the higher its altitude is in complete disagreement with the General Theory which predicts the opposite. We know of no experimental evidence one way or another in this regard.

E. Here we make the following observations with regard to another derivation of the time dilation formula of the General Theory near a spherical body. Within the spirit of GM, what is relevant to the rate of a clock is the total number of gravitons and average frequency of the gravitons the clock receives. How or why this is so, is of course not known. Different gravitational fields only effect the number of gravitons (we are talking about say two clocks at different heights above the earth) and not the average frequency, which should remain constant in this case. In an isotropic field, velocity would only effect the average frequency. It would then seem reasonable to expect that one can change the number or frequency of gravitons to produce the same effect. That is, one would expect to be able to have two clocks with the same rate in different intensity fields because one clock could have enough velocity to "make up" for the difference in intensity of gravitons. So with this assumption one is led to expect a relationship between velocity and intensity of a field. One has such a relationship (using the gravitational potential in place of the gravitational intensity) in the formula

$$Mv^2/2 + \phi M = \text{constant}$$

which gives the law of conservation of energy in a gravitational field, where M is the mass, v is the velocity and ϕ is the gravitational potential. Choosing v and ϕ equal to zero at infinity makes the constant equal to zero. This gives

$$v^2 = -2\phi$$

then using the formula from the Special Theory

$$\Delta t = \Delta t_0/\sqrt{1 - v^2/c^2}$$

one gets

$$\Delta t = \Delta t_0/\sqrt{1 + 2\phi/c^2}$$

which is the formula one would use in the General Theory and is verified by the previously mentioned experiments.

F. The section on gravitation shows that GM is consistent with an inverse square law. General Relativity says that gravitational forces do not quite satisfy an inverse square, and experience bears this out (i.e., the perihelion of Mercury) This is not derivable from GM yet, but it is not necessarily incompatible with GM either. This is because GM would only give an inverse square law in the perfect statistical situation, that is, in a completely uniform distribution of gravitons in space and time. It seems quite reasonable to expect that there would be slight deviations from an inverse square law near a very large body such as the sun.

7. *Problems*

In this section several inadequacies of GM are discussed. Since no structure has been presented to give quantitative predictions, we are only referring to problems of a qualitative and philosophical nature.

A. To us the most serious objection to GM is of a philosophical nature. That is, if we are to explain gravitational forces from the principle of the conservation of momentum, it only seems reasonable and desirable that the other forces should have an analogous nature. Nuclear forces are very complicated, the fact that they vary in so many ways with such strange functions of distance is not the disturbing part in principle. Because of the very small distances involved, one would expect the resultant statistical deviation of any "photon" flux near a nucleus to be very great, which could lead to some strange effects. The problem is the existence of both attractive and repulsive forces comparable to the situation with electromagnetic forces.

Consider trying to explain the repulsive force that exists between two electrons by using the conservation of momentum of some background flux of appropriate photons. It cannot be done in any direct manner that we can see. It is clear that one cannot consider the repulsive force arising from the emission of "photons" from the electrons themselves and not from the background since one would then have fatal problems with an obvious conservation type principle. That is, the electrons would eventually run out of these "photons." To consider the possibility that they are being "replaced" from universal sources would make the situation analogous to gravitons. That is, only lead to an attractive force.

It is known that a small sphere in a one directional photon field (Kerker, 1974) can move in the opposite direction to the flux, but only in the presence of other objects and not in a vacuum. This is because of the radiometric forces. Perhaps one could imagine some similar mechanism in this case to get a repulsive force, but it is hard to see how to do this even by the rather loose standards of this article.

Another possible way of attack would be to imagine that it was possible for some "photons" to become trapped between two matter objects constantly bouncing back and forth. Then if the objects were "close enough," a repulsive force could result because of the number of repeated collisions the "photons" would undergo. As the distance between the objects grew the force would become an attractive force because the outside flux of "photons" would overcome the effect of the repeated collisions of the trapped "photons." "Close enough" would have significance only relative to the "photon" flux or density. One could imagine from the previous discussion that gravitons could cause a repulsive force at very small distances, then at larger distances cause an attractive force and finally at extremely large distances (say for objects on the periphery of the universe) cause a repulsive force again.

B. In the sections on Gravitation and General Relativity it was stated that it was not necessary to speak of the inertia and momentum of matter objects relative to space but only relative to some mean distribution of gravitons. The question of photons having momentum intrinsic to themselves was avoided. We have no satisfactory answer to this question. It is remarked that these "things" are a rather special class of objects, namely those objects which have no rest mass, and in an "unbound" state always have the velocity c. Perhaps therein lies the path to the answer.

C. The problem of the creation and annihilation of photons as manifested in pair production is not even approached by GM.

8. *The Experimental Situation*

There are currently two qualitative predictions of GM that would differ from the existing theory of General Relativity. The first, that the length of a rod would become shorter as its distance from the earth was increased, was discussed in Section 6-D. This prediction required several additional seemingly reasonable assumptions about the nature of time. The second was proposed in the article by Buonomano and Moore (1973). To the best of our limited experimental knowledge this is a feasible experiment which, if positive, could dramatically decide between the existing theory of relativity and GM as applied to relativity. This experiment is described again below (Part D), where also a more complete theoretical discussion is presented than the limited one in that article. First it is necessary to discuss the so-called rotor type experiment in relationship to the Doppler Effect. It is assumed that the reader is basically familiar with this type of experiment (see Kundig, Turner & Hill, Champeney *et al.* or Hay *et al.*).

A. The rotor type experiment is important because it provides, through the use of the very high sensitivity of the Mossbauer effect, a means of comparing the rhythm of two spacially separated "clocks" at exactly an angle of 90 degrees (this angle is necessary because otherwise the first-order Doppler Effect would dominate the measurements, and in practice the only way to guarantee this angle is by the rotation of one "clock" around the other).

Consider the situation illustrated in Figure (1). The velocity $\bar{u}$ (a vector) of C2 relative to SP is to a first approximation

$$\bar{u} = (v - w \sin (TH), w \cos (TH))$$

and

$$u = \sqrt{v^2 + w^2 - 2vw \sin (TH)}$$

Depending on TH, the velocity of C2 relative to SP, is sometimes greater than C1 and sometimes less, varying between $(v - w)/(1 - vw/c^2)$ and $(v + w)/(1 + vw/c^2)$ for $TH = \pi/2$ and $TH = 3\pi/2$, respectively. This then means that C2 sometimes runs faster than Cl and sometimes slower, and has approximately the same rhythm for $\sin (TH) = w/2v$.

B. Because of this several researchers who also advocate a "Lorentzian type" theory (see Buonomano & Moore, 1974) have proposed using a rotor experiment to discover this change of rhythm of C2 as a function of angle. This can not be done, because when one assumes a "preferred" frame one should also make a distinction between the velocity of the emitter (source) and absorber (observer) relative to that "preferred" frame as in classical physics. When one does this it is found that the Relativistic Doppler Formula is valid. Consequently, with this type of experiment this angular dependence of rhythm cannot be detected. More accurately what has been proved (Buonomano & Moore, 1974) is the following: The Relativistic Doppler Formula is completely derivable from any theory of special relativity which assumes the existence of a preferred reference frame, real time dilations, real length contractions, and uses the classical distinction between the velocity of the source and the observer. This is expressed by the formula

$$\nu_0 = \nu_s[1 - (v_0/c)\cos(\theta_p)]\gamma_{v_s}/[1 - (v_s/c)\cos(\theta_p)]\gamma_v$$
$$= \nu_s[1 - (w/c)\cos(\theta_s)]/\gamma_w$$

where v_0 and v_s are the velocities of the source and observer respectively relative to SP. ν_s and ν_0 are the frequencies as measured in reference frames fixed with the source and observer respectively. w is the velocity of the reference frame of the observer relative to the reference frame of the source. θ_p and θ_s are the angles as measured in SP and in a reference frame fixed with the source respectively. γ_v is

$$\gamma_v = \sqrt{1 - v^2/c^2}$$

In the proof, the first equation is assumed to be the "natural" Doppler Formula in such a theory. It is just the classical Doppler Formula modified in the obvious way relative to the consideration of real time dilations. This proof does not depend on the assumption of the invariance of the phase of a wave.

C. Within the context of the theory presented, the above result is only valid in an isotropic gravitation field. The reason is that what makes the above formula derivable is the particular expression

$$T_0 = T/\sqrt{1 - v^2/c^2}$$

which in turn is a reflection of the gravitational energy the clock receives as per Assumption (2.7). In the case of a large anisotropy it only seems reasonable to assume that the energy a clock receives would be quite direction-dependent and therefore expressed by an entirely different function of velocity. (It is not inconceivable that the previous formula could also be derived even in this case, but this would entail making what would seem to be, at this point, unreasonable assumptions. If this could be done, the experiment proposed below would not serve as a test.) This fact can be made clearer by considering the extreme case where the gravitational field is entirely from one direction. The gravitational energy a clock would receive in this situation is quite direction dependent (the reader is reminded that the intensity of the field is always considered to be uniform). There is no inertial frame here that has the property of the "preferred" frame in an isotropic uniform gravitational field, in that it represents a frame that receives the minimum gravitational energy of any other frame in the same field (see Buonomano, 1974; Section 5-C).

D. Now consider the experiment proposed by Buonomano and Moore (1973) which is illustrated in Figure 2. Here the intensity of the earth's gravitational field is the same at Positions 1 and 2. But at Position 1 the absorber has a velocity w into the earth's field, while at Position 2 it has the velocity w in the opposite direction. Therefore, according to the hypothesis that the rhythm of a clock is determined by the frequency at which it "perceives" the gravitational waves, the absorber must experience a greater

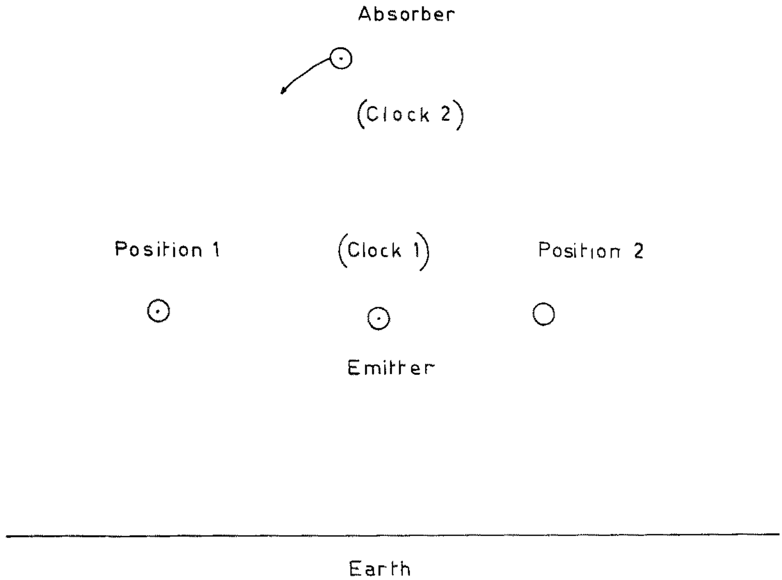

Figure 2—The rotor is rotating so that its axis of rotation is parallel to the surface of the earth. The tangential velocity of the absorber is w. Positions 1 and 2 are equidistant from the earth.

dilation at Position 1 than at Position 2. This experiment is quite different than the one illustrated in Figure 1 because of the anisotropy of the field due to the earth. When the rotor is rotating in the plane of the earth, there is no anisotropy because the earth's gravitational field can be ignored with regard to the velocities of the "clocks" in that plane (this must really be considered an assumption) since it is perpendicular to the field. This is not the case in the proposed experiment.

E. So the prediction is that at Position 1, C2 will have a different rhythm than at Position 2 relative to C1, and that this will be measurable by the methods used in the above-quoted rotor experiments. This is strictly a qualitative prediction since there is no mathematical framework to give a quantitative prediction.

Note though that this is in disagreement with both the Special and General Theories of Relativity using the Schwarzschild, Kerr or "rotation" (Moller, 1972) Metrics. That this qualitative prediction does not come from the Special Theory or the "rotation" Metric is easy to see. That it is not derivable using the Schwarzschild Metric is seen to follow from the fact that all the differentials in this metric are quadratic. This implies that the direction in which the absorber is moving is irrelevant, and that the absorber as a clock would have the same rhythm at both Positions 1and 2. This same thing essentially happens with the Kerr Metric since the plane of rotation can be chosen (it only need remain perpendicular to the plane of the surface of the earth) so that the nonquadratic spatial differentials are identical for C2 at both Positions 1 and 2.

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* Because some of these references only became known to us during the writing of this paper, we have not yet been able to obtain copies of all of them. We include these references for the convenience of the reader. The ones marked with an * have not been read by us, and therefore we are not sure if they bear on this article.